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REPORT

ON

APPARATUS

FOR THE USE OF

FUSIBLE ALLOYS

IN

STEAM BOILERS.

REPORT.

PHILADELPHIA, AUG. 1855.

HON. JAMES GUTHRIE,
Secretary of the Treasury,

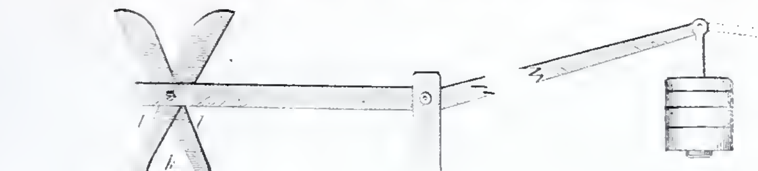
SIR :—

Having performed a series of experiments on the forms of apparatus in which fusible alloys may be employed for the purpose of indicating excessive temperature and pressure in steam-boilers, I herewith submit to the Department a Report on the results and conclusions at which I have arrived.

Since any given pressure in a boiler has a corresponding temperature, a determination of the latter will indicate pressure as accurately as direct measurement. A convenient method of ascertaining such temperatures is to employ alloys fusing at fixed thermometric points. A set of alloys, with melting points corresponding to pressures from 60 lb. to 160 lb., having been made for use under the Treasury Department, an important question next arises as to the best methods of employing them.

They may be applied to boilers in two ways: First, by inserting plugs of an alloy into an opening in a boiler; when the proper limit of temperature is exceeded, the plug should fuse, flow out of the opening, and allow the escape of steam, which will be a sufficient indication of excessive pressure. In this case the alloy itself is a safety-valve. Second, by a mechanical arrangement, containing the alloy in a steam-tight tube, thrust into the boiler, so that when the alloy melts, it loosens a force restrained by the solid alloy, and gives motion outside the boiler. The motion may be communicated to a valve to blow off steam, or to other mechanical alarm.

APPARATUS FOR THE USE OF FUSIBLE ALLOYS IN STEAM BOILERS.



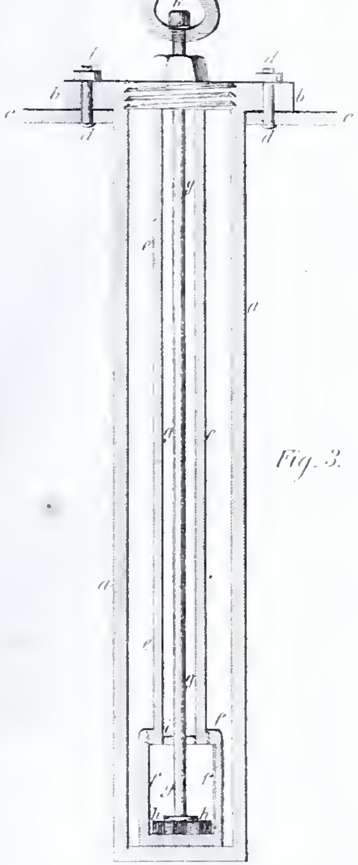
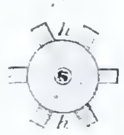


Fig. 3.



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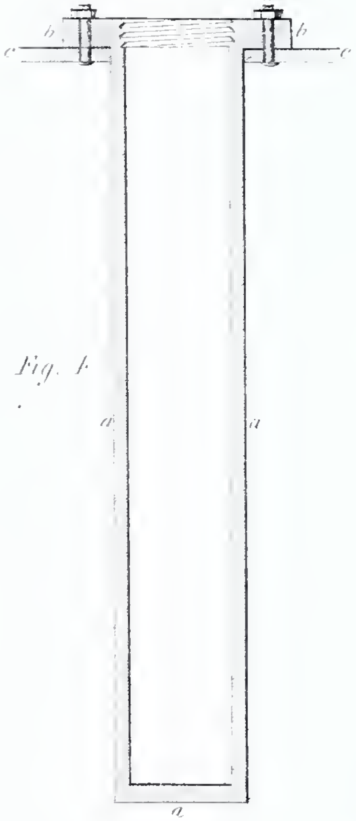

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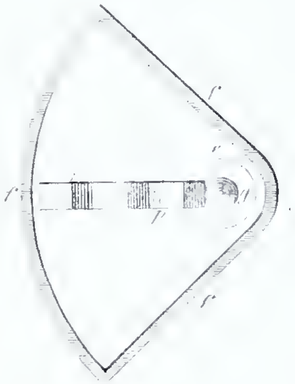


Fig. 11.

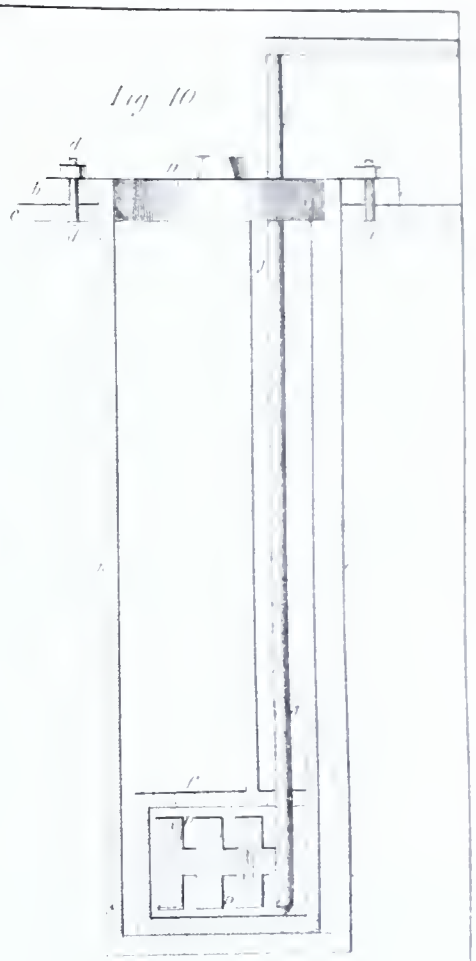
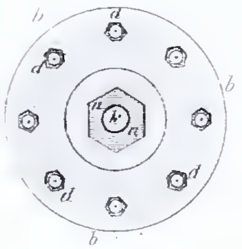


Fig. 10.



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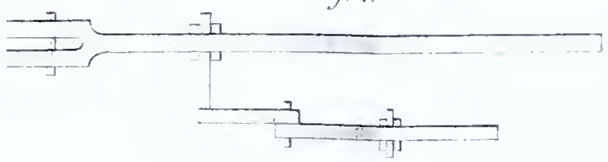

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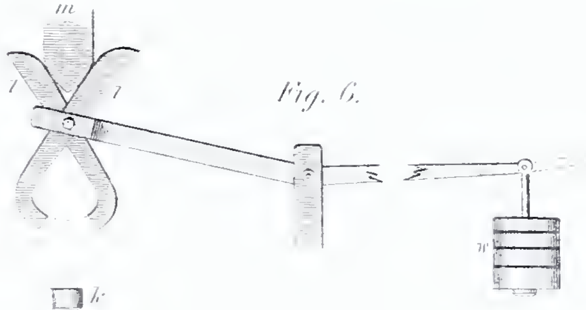
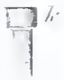
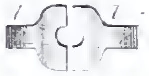


Fig. 6.





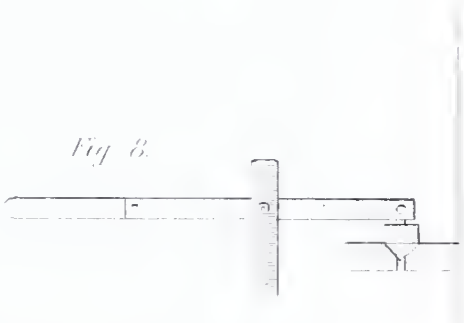


Fig. 8.

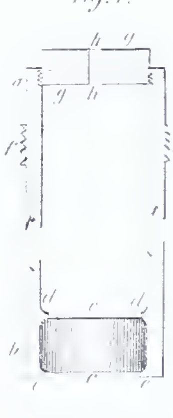


Fig. 1.

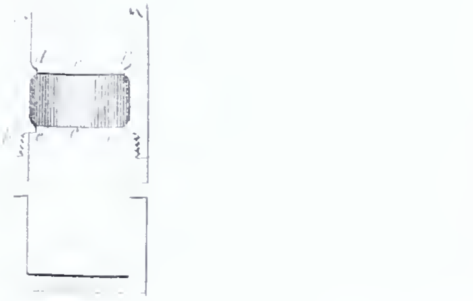


Fig. 2.

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Plugs.—In many fusible alloys portions of the component metals are capable of forming new combinations, which melt at much lower temperatures, some even below the boiling point of water. When one of these alloys, therefore, is gradually heated, and exposed on one side to a greater pressure than on the other,—the very conditions under which the plugs are employed,—the most fusible alloys are liable to melt first, and to be forced out through the rest of the plug. The spongy residue still forms an alloy, but one which fuses at a much higher temperature than the original plug; and this remainder may be of such a form, size and tenacity, as to keep the orifice in the boiler closed. In such case the assigned limit of pressure in a boiler might be greatly exceeded without an audible alarm from the safety plug. Thus, if a plug of the alloy, representing 80 lb. pressure, (fusing at 321°), were inserted into an opening in a boiler, and the heat gradually increased, an alloy, commonly known as fusible metal, and melting below 212°, might segregate and eliquate; and it is possible and even likely that from one-half to two-thirds of the original weight of the plug would remain, with its melting point raised to some 380°, which corresponds to about 190 lb. pressure.

From experiment I infer that, of the alloys hitherto made by me for the Treasury Department, those for pressures above 120lb. may be safely employed in the form of plugs. A series of experiments recently made on alloys of very different compositions has led to the conclusion that they may be confidently used as plugs for pressures of 110 and 120 lb. For pressures between 60 and 100 lb. inclusive, I cannot at present recommend their use in the form of plugs, where human life is involved in the recommendation; but I still hope by perseverance to discover other compositions of metals, whereby all the higher pressures at least may be determined and limited by plugs.

Since the plug is the simplest form of application of fusible alloys, I have presented in figures 1 and 2 my views of the manner in which it may be employed most efficiently.

Fig. 1. *a b.* is an iron tube of any convenient length, the upper and lower parts only being represented; *c* the fusible plug cast in the lower end *b*, and held firmly by projecting rings or flanges *d e*. To facilitate the casting of a suitable quantity of metal, the lower end of the tube *a b* should be unscrewed from it; *f* is a screw cut on the upper end of the tube to secure it to the boiler by means of a plate, as described below under figs. 3 and 4; *g* a cylinder of metal screwed into the upper end of the tube *a b*, and perforated by a small hole *h*, which allows the escape of only a small quantity of steam, but sufficient to give audible alarm, when the plug fuses and flows down. To prevent the metal when fused from running into the boiler, a cup, or piece of tube closed at the bottom, may be screwed to the end of the tube *a b*, and is provided with lateral openings for the admission of steam. The proportions which appear to me best adapted to the purpose are from $\frac{3}{4}$ to one inch for the thickness or height of the fusible plug, and not less than one inch for its diameter.

The advantages of the plug over other more complex arrangements are its simplicity and cheapness. From my experiments I believe it will also prove efficient and safe for the alloys expressing from 110 to 160 lb. pressure. On the other hand, its range of application is limited; if the lower end exposed to the steam should become clogged with a hard deposite, the metal might fuse without escaping, and prevent its indicating danger; or, if the alloy should melt and flow out, it could not be replaced without letting the steam down entirely, entailing on a boat considerable loss of time. It admits of a question, however, whether the instruction conveyd to an engineer in the last named objection might not be more lasting. The use of the cup to catch the fused metal is peculiarly liable to the second objection, the tendency to fill up with deposite. Where safety should be the principal consideration, the enclosed arrangements now to be described, are in my estimation preferable to the plug, in spite of its simplicity and economy.

Mechanical arrangements.—Of these I have tried several, all of them depending upon the same principle, viz: the fixation of a piece of iron in the solid alloy, and its movement when the alloy melts. They further differ from plugs in not being exposed to the direct action of steam on the alloy, and therefore, not so liable to segregation and eliquation into more and into less fusible alloys. In these arrangements all the alloys, which have been made by me for the Department may be employed, from 60 to 160 lb. inclusive.

There are several modes of obtaining motion in the alloy, circularly, upward, downward, and laterally, and according to these movements four different machines may be constructed.

1. *Circular movement.*—This is the movement in what is commonly called Evans' Safety Guard. A tube of iron, with a strong metallic box on the end, containing the fusible alloy, is inserted into a boiler. A rod of iron passes through the tube into the alloy in the box, terminating at this end in a paddle or star-shaped wheel, while the other end projects above the boiler, and is wound around with a chain, to which is attached a weight or spring. As long as the alloy is solid, the rod cannot revolve, but upon its fusion, the weight or spring unwraps the chain by the revolution of the rod. The motion may be transferred to a valve or other alarm. After motion given, time is allowed to the alloy to solidify by cooling the boiler, when the chain is again wound around the spindle on the end of the rod, and the machine once more set.

This machine works very well in practice, if duly watched, but may be still further improved. Instead of clamping the tube into a small opening in the boiler it may be rendered more steam tight by screwing it into a thick plate of iron, and securing this on the boiler by six or eight bolts and nuts. This is the plan adopted in the small boiler with which I have experimented.—Again, the rod passes too loosely through the lower end of the tube next to the box, so that the rapid revolution of the wheel or paddle throws up the melted alloy into the tube. Contracting the end of the tube to avoid this objection was an improvement introduced, I have been informed, by a machinist of Cincinnati. One feature in this machine and in others requires that it should be frequently examined in order to its correctly operating. Since the iron rod necessarily passes through a narrow opening at the upper end of the tube, it is there liable to rust, in which case more force would be required to produce revolution at the same temperature ; or, which is the same in substance, where the weight remains constant, the steam must be more highly heated to render the alloy more fluid. I found that where the rod had rusted a little, it required an increase of heat, equivalent to 20 lb. above that marked on the alloy, to produce motion; whereas, after removing the rust, and greasing the rod, the machine moved at the precise point designated on the alloy. I can readily imagine rust to accumulate through neglect to such an extent, as to prevent the apparatus from moving at any pressure in a boiler. The machine should therefore, be examined from time to time, and those parts oiled where friction from rust is likely to retard its movement.

2. *Vertical movement.* A downward motion in fusible alloy was proposed many years since by Mr. Cadwalader Evans, and about the same period an upward one by Prof. A. D. Bache. The former also suggested a closed iron tube to prevent the loss of melted alloy. The observations of the Committee of the Franklin Institute on the segregating tendency of fusible alloys, led them to recommend enclosing the alloys in steam-tight apparatus. Observing that the guard cannot be taken out when the steam is up, I am induced to suggest a more permanent arrangement for the steam-tight tube, so that the apparatus containing the alloy may be removed at any time for repair or inspection. In the arrangement now to be described this feature is introduced, with the upward movement, but I may observe that the downward movement may be similarly employed, and the permanent casing may be dispensed with.

In the accompanying drawings like parts are represented by like letters. Fig. 3 represents a vertical section of the whole apparatus. Fig. 4 shows the steam-tight casing *a* of wrought iron, firmly secured to a thick plate of cast-iron *b* (figs. 3, 4, 9), and the whole fastened in the top plate of a boiler *c*, by the bolts and nuts *d*. The tube *e*, fig. 3, screwed into the box *f* and containing the rod *g*, is secured by a large screw to the plate *b*. The box *f* contains the fusible alloy. At the lower end of the rod *g* is a plunger *h*, represented in horizontal section in fig. 5. On the upper end of the rod is a head *k*, by means of which the nippers *l* (figs. 3, 6,) hold the rod and raise it when the alloy fuses. When the whole apparatus is set, as in fig. 3, the plunger is at the bottom of the solid alloy, which prevents its elevation by the weight *w* on the further end of the lever; but when the alloy has attained its melting point, the weight instantly raises the plunger, and the motion is used to open a valve or give other alarm. A lever attached to the upper end of the rod would be a simpler arrangement than that shown in the drawing, but the latter is given suggestively to show that the apparatus may be so constructed as to reset itself, after it has once operated. In this case, when the plunger rises near to the top of the box, a wedge *m* opens the opposite ends of the nippers, and lets the rod with its plunger fall down again to its proper position. When the boiler has sufficiently cooled to solidify the alloy, the nippers are again depressed to hold the rod.

Fig. 3 shows the apparatus set, and with its lever extended to open a valve. Fig. 6, exhibits the same after the alloy has fused and the rod fallen back to its position. Figs. 7 and 8 show another method of communicating motion to a valve, by an extension of the fulcrum or axle of the lever. Fig. 9 exhibits a horizontal view of the upper end of the plate *b*, the bolts and nuts *d*, and large nut *n*, by which the interior tube, box and rod, are screwed into the plate, and by which they may be at any time removed.

3. *Lateral movement.* The features of this arrangement are represented in figs. 10 and 11; fig. 10 being a vertical section of the apparatus, and fig. 11 a horizontal section of the box and gate at the lower end of the rod. *a*, *b*, *c*, *d*, *e*, *g*, are similar to those parts in the previous figures, except that the tube passes down on one side of the steam-tight casing *a*. The box *f* is a portion of a short cylinder, the top of which is capable of being removed to introduce the gate, and the tube *e* screws into this top near the centre of the cylinder, as shown by a light line in fig. 11. When the fusible alloy in the box is melted, the gate moves through it, and the motion of the upper end of the rod is readily transferred to a valve.

A comparison of the several methods of obtaining motion, by the act of melting fusible alloys, shows 1st, that sufficient motion can be given by all of them; for although the extent of movement in Evans' Guard is only limited by the number of coils of chain around the spindle, yet it is also evident that only a small movement is necessary to open a valve or produce any desired alarm —2nd, that the apparatus may be placed vertically, or in a moderately inclined position; for although fig. 3 is designed in the drawing to show the apparatus in a vertical position, yet an inclination may be given to it, so that it can reset itself, by using a bent lever or by adapting a spring to the head *k* of the rod *g*, that will drive it down again, when released by the nippers. A very sloping direction cannot be given in any of the arrangements noticed, since the rod cannot pass so tightly through the lower piece *i* in the tube *e*, as to prevent the fused metal from flowing out, when the whole apparatus is too much inclined.

Other kinds of motion in the alloys can be imagined, such as of a lever placed vertically in an oblong box and tube, with its fulcrum about the middle—or of a wheel moving on a horizontal axle, and its motion carried outside the boiler by an endless chain—but these and the above are merely thrown out suggestively, in order that machinists may avail themselves of the principles involved in them, and bring them into successful operation.

I have the honor to be,
very respectfully,
your obedient servant,

JAMES C. BOOTH.